

The Development of Single Star Scidar for Tibet and Dome A

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Abstract.

A Single Star Scidar system(SSS) has been developed for remotely sensing atmospheric turbulence profiles. The SSS consists of computing the spatial auto/cross-correlation functions of short exposure images of the scintillation patterns produced by a single star, and provides the vertical profiles of optical turbulence intensity $C_n^2(h)$ and wind speed $V(h)$. The SSS needs only a 40cm aperture telescope, so that can be portable and equipped easily to field candidate sites. Some experiments for the SSS have been made in Beijing last year, successfully retrieving atmospheric turbulence and wind profiles from the ground to 30km. The SSS observations has recently been made at the Xinglong station of NAOC, characterizing atmospheric parameters at this station. We plan to automatize SSS instrument and run remote observation via internet; a more friendly auto-SSS system will be set up and make use at the candidate sites in Tibet and Dome A.

1. Introduction

The atmospheric transparency and stability are the preferred indicators for the quality of ground-based astronomical observatory. Atmospheric optical turbulence seriously affects the performance of large optical-infrared telescopes. The development of detection technique to atmospheric optical turbulence will provide with scientific judgment for site selection and evaluation, and also with valuable database for other research projects, such as design of adaptive optical system, atmospheric optical communication, and detection of space objects.

Because the profiles of atmospheric optical turbulence is very important to evaluate astronomical sites, we have performed investigation into the related techniques, and finally made decision to develop an advanced instrument called Scidar (SCIntillation Detection and Ranging)[1, 2]. Scidar is one technology at most in details for monitoring optical turbulence, and has been employed on some existing observatories. Scidar can detect multiple layers of atmospheric turbulence, with much higher spatial resolution, which is very important for site evaluation and adaptive optics application. Previously, the disadvantage of

Scidar technique is aperture requirement for a telescope, usually larger than $1m$, and it is difficult to use on field candidate sites in the early stage of site testing.

Our aim is to develop a Single Star Scidar[3], the most advanced technology currently for measuring vertical profile of optical turbulence. This SSS needs only a $40cm$ telescope, which make it portable and equipped easily to the field candidate sites, such as in west China and Antarctic Dome A. The monitoring results will provide knowledge of detailed turbulence profiles on-site for the next generation large telescopes of China.

2. Instrument

Fig.1 shows the SSS system installed at the Xinglong station of National Astronomical Observatories, CAS. The SSS configuration is as the following: 1) a $40cm$ Meade LX200 tube on an Astro-Physics 1200 equatorial mount; 2) a collimating lens at the focus of the telescope, to make the beam parallel; 3) a 640×480 Pixelfly CCD camera, attached under the collimating lens for fast sampling star scintillation pattern; 4) an auto guide system with a LPI CCD.

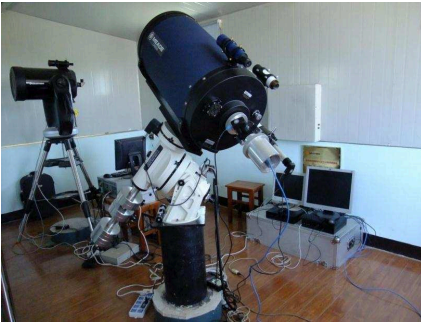


Figure 1. The SSS system installed at Xinglong Station.

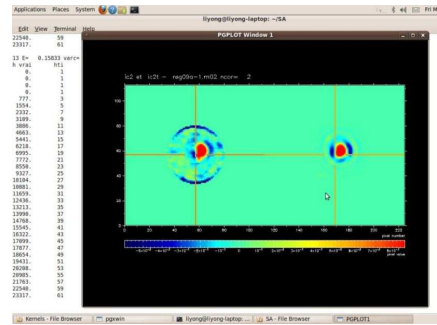


Figure 2. The “simulated annealing” process for reconstructing observation results.

The SSS is a new technique for retrieving atmospheric turbulence profile by analysis of single star scintillation. The scintillation patterns are analyzed in real time, by computing the spatial auto-correlation and at least two cross-correlation images performed by a dual core computer. Fig.2 displays the results of temporal cross-correlation of scintillation pattern at $2\Delta T$ (left), and the same function reconstructed with simulated annealing algorithm(right). The off-line processes let assess both optical turbulence and wind speed profiles using the simulated annealing method.

3. Observations and Results

The SSS instrument was constructed and at first made experiments in Beijing, and then shipped to Xinglong Station, which is located at $N40^{\circ}23'$, $E117^{\circ}35'$, $950m$ high and 170 miles northeast to Beijing. The SSS observations were carried out in several periods from April to September, 2011. We have successfully obtained the profiles of optical turbulence and wind speed, as well as the key parameters of optical turbulence, seeing, coherence length, coherence time, and isoplanatic angle.

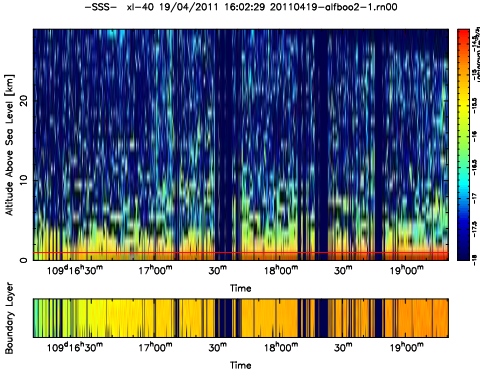


Figure 3. Temporal evolution of $C_n^2(h, t)$ on 19 April 2011.

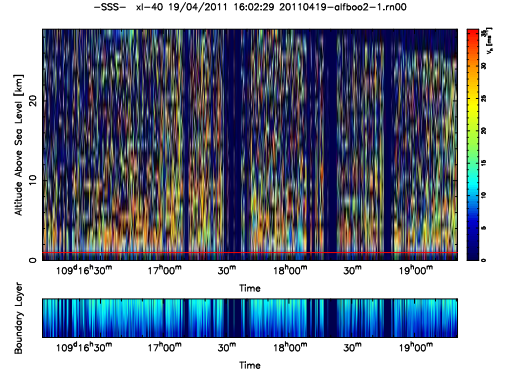


Figure 4. Temporal evolution of $|V(h, t)|$ on 19 April 2011.

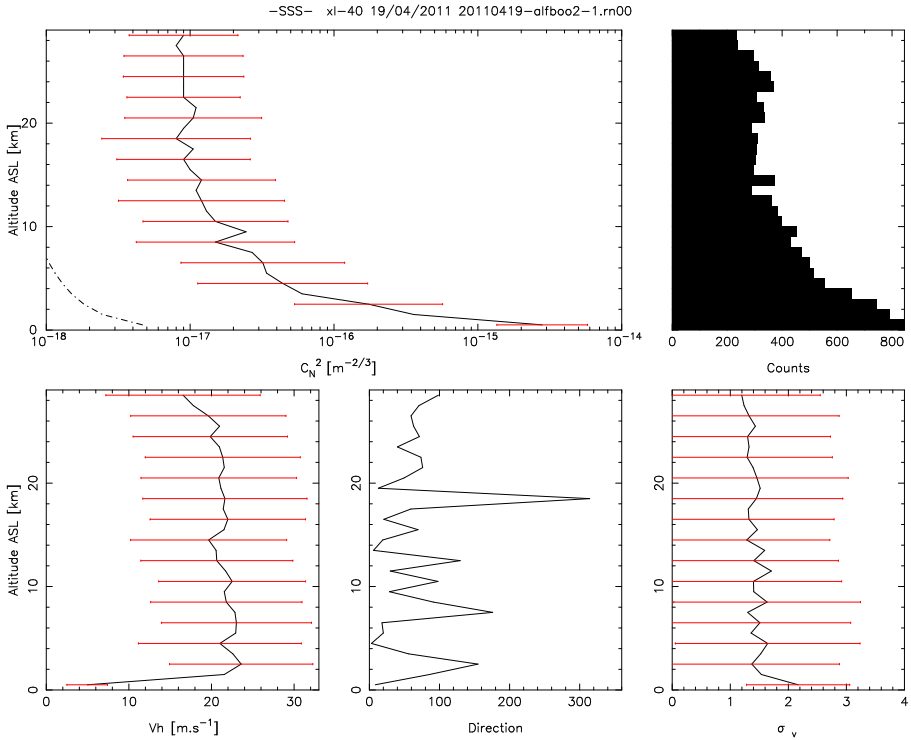


Figure 5. The profiles of optical turbulence and wind speed. All profiles were measured by SSS on 19 April 2011, at Xinglong station.

Fig.3 and Fig.4 are the temporal evolution of the optical turbulence and the wind speed modulus simultaneously. Fig.5 shows the median vertical profiles of turbulence(*top – left*), the frequency counts of detected layers(*top – right*); the profile of mean speed modulus and mean wind direction(*bottom – left*), and the mean vertical profile of the wind speed standard deviation(*bottom – right*).

From top left to bottom right, Fig.6 shows the temporal evolution of the seeing, the coherence volume[4], the isoplanatic angle, and the time coherence;

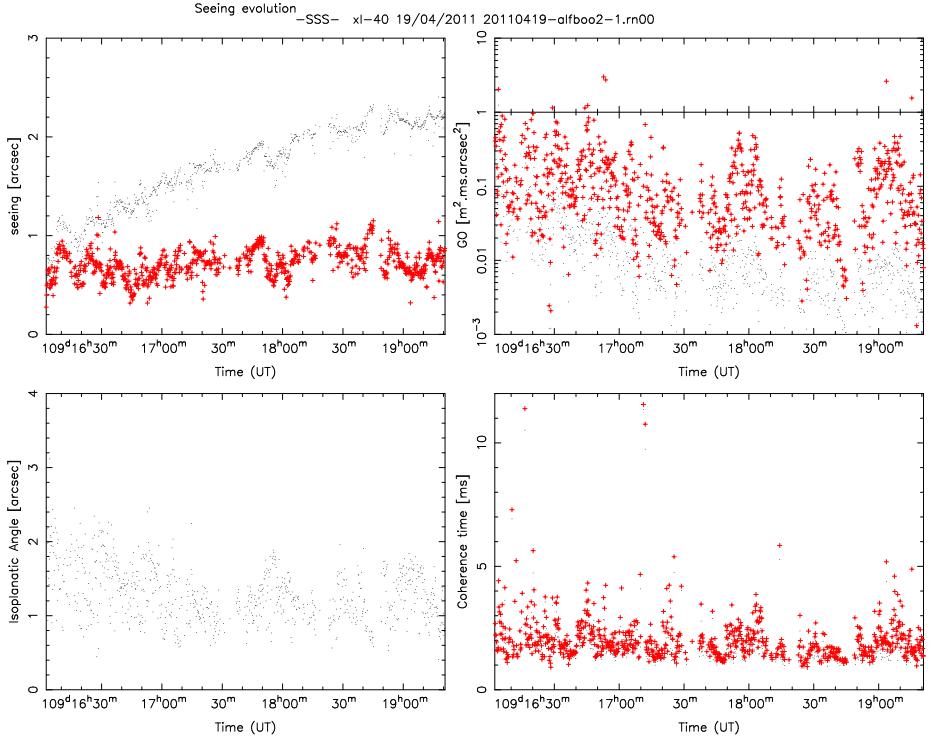


Figure 6. The temporal evolution of the key parameters of optical turbulence on 19 April 2011.

these key parameters of optical turbulence can be deduced from the knowledge of optical turbulence and wind speed profiles.

4. Conclusion

We have developed a Single Star Scidar system for astronomical site testing. The SSS can provide vertical profiles of turbulence intensity and wind speed from ground up to an altitude of 30km . The SSS can employ only a 40cm telescope, making it portable and equipped easily at field candidate sites.

There is a plan to upgrade the SSS system and make an auto-SSS system with more friendly control, so that our SSS can be usable under the formidable conditions at Tibetan high plateau and Dome A, Antarctica.

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